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REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
10/22/01

3. REPORT TYPE AND DATES COVERED
Final Progress, 8/1/97 - 8/15/01

4. TITLE AND SUBTITLE
Development of An Integrated Proximity Effect Correction Scheme

5. FUNDING NUMBERS
DAAG55-97-1-0325

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park,, NC 27709-2211

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
31523.6-PH

11. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12 b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

Abstract

The **specific aim** of this project is to develop an integrated proximity effect correction package which can handle sub-0.1 μm feature size, heterogeneous substrates, exploits both of dose and shape modification, and is applicable to projection or multiple electron beam lithographic systems as well as single (Gaussian) beam systems. Also, the software is to be parallelized for fast correction exploiting a readily available network of workstations.

As reported in the interim progress reports and this final progress report, the proposed research project has been successfully completed.

20020201 063

14. SUBJECT TERMS

15. NUMBER IF PAGES
2

16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

1 Summary of Results

Only a brief summary of the results is provided in this final report as required in the reporting instruction. For details, refer to the annual interim report submitted each year.

1.1 Heterogeneous Substrates

The proximity effect correction schemes developed in the past were all for homogeneous substrates on which the electron scattering characteristic is space-invariant. A simple but effective approach has been implemented in order to allow PYRAMID to correct patterns for heterogeneous substrates.

1.2 Hybrid Correction

The main objective of the hybrid approach is to control spatial distribution of global exposure due to back-scattering to facilitate local shape correction with (*i*) maintaining the advantages of uniform dose as much as possible, (*ii*) automating the procedures of determining dose distribution, and (*iii*) minimizing computation required. A practical fast scheme for determining spatial dose distribution has been designed.

1.3 Dose Correction

PYRAMID 1.0 adopts the shape modification approach to proximity correction. As an effort to develop an integrated proximity correction package and also to demonstrate the flexibility of PYRAMID, a dose modification version of PYRAMID has been implemented. Two different implementations of dose modification have been considered, i.e., recursive ("sequential") and non-recursive ("simultaneous") corrections. The simulation results indicate that the PYRAMID approach is flexible enough to handle both of dose and shape modifications efficiently, and that the dose modification version, especially simultaneous correction, has a potential to improve correction accuracy significantly over the shape modification version especially for fine-feature patterns, but at the expense of a longer correction time.

1.4 Optimization

1.4.1 Selection of Critical Points

Selection of control points heavily affects accuracy and speed of proximity correction. A simple but effective method for adaptively selecting control points has been designed. Through extensive computer simulation, it has been shown that the adaptive selection scheme can improve correction accuracy significantly over the fixed selection scheme.

1.4.2 Neural Network

A backpropagation neural network (BNN) algorithm has been designed in order to improve correction accuracy. In this model, circuit elements in a group are corrected "simultaneously," thereby overcoming the recursive nature of sequential correction.

1.5 Dependency of Correction Accuracy

Accuracy of E-beam proximity correction, which can be achieved, depends on several parameters such as the forward and backward scattering ranges of electrons, feature size, dose quantization interval, etc. Dependency of correction accuracy on such parameters is analyzed as an effort to find out the limit of proximity effect correction in E-beam lithography.

1.6 Data Handling

A hierarchical pattern representation format specifying *extent* information on each node to reduce the searching time has been designed and its detailed performance analysis has been carried out. More specifically, dependency of data size and correction time requirements on each of the parameters involved in a hierarchical representation, has been analyzed in detail.

1.7 Parallel Correction

As the circuit size and density continue to increase, (*i*) the time-consuming nature of proximity effect correction will be even more so, and (*ii*) the computer memory required will be well beyond the size of memory available on a workstation. As an efficient and practical solution to these two problems, proximity effect correction has been parallelized using a network of workstations.

2 Journal Publications:

- S.-Y. Lee, and Jayesh Laddha, "Adaptive Selection of Control Points for Improving Accuracy and Speed of Proximity Effect Correction", *J. of Vac. Sci. and Technol.*, B 16(6), pp3269-3274, November/December 1998.
- S.-Y. Lee and G.D. Ghare, "Distributed Proximity Effect Correction on a Network of Workstations", *Microelectronic Engineering*, pp.291-294, 46, 1999.
- S.-Y. Lee, and Jayesh Laddha, "Application of Neural Network to Enhancing Accuracy of E-beam Proximity Effect Correction", *Microelectronic Engineering*, pp.317-320, vol. 53, 2000.
- S.-Y. Lee, "PYRAMID - A Hierarchical Approach to Proximity Effect Correction: Review and Update," (*invited paper*) *Recent Research and Development in Vacuum Science and Technology*, Transworld Research Network, 2 (2000), pp289-296.
- S.-Y. Lee and J. Laddha, "Automatic Determination of Spatial Dose Distribution for Improved Accuracy in E-beam Proximity Effect Correction," to appear in *Microelectronic Engineering*, 2001.
- S.-Y. Lee and J. Laddha, "A Hierarchical Circuit Pattern Representation Format for Efficient E-beam Proximity Effect Correction," to appear in *Microelectronic Engineering*, 2001.

3 Theses:

- M.S. thesis, Jayesh Laddha, "An Efficient Hierarchical Pattern Representation Format for Proximity Effect Correction in E-beam Lithography," January 2000.
- M.S. thesis, Dake He, "An Extension of the Dose Modification PYRAMID: Circuit Primitive Partitioning and Simultaneous Correction," December 2000.

4 Scientific Personnel:

- **PI:** S.-Y. Lee
- **Graduate Students:**
  - Gautam Ghare (M.S. degree)
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5 Technology Transfer:

PYRAMID Version 1.0 licensed to Nabity Lithographic System Inc., Bozeman, MT.